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V- SUMMARY

Some mites and coleopterous insects are of great economic importance of stored products in many parts of the world, especially in Egypt where the climate is temperate and large quantities of legume crops are grown and stored.

The present work was initiated in September 1998 and terminated in June 2003, to study the ecology, biology and biological control of mites and coleopterous insect species associated with stored legume crops. The influence of some environmental factors on the distribution and abundance of mites and coleopterans were studied and discussed.

1. Ecological Studies:

1.1. <u>Seasonal abundance of mite suborders and coleopterous insects associated with stored legume crops</u>:

1.1.1. The first season (September 1998 – August 1999):

A preliminary study was carried out on ten-stored legume crops.

a. Broad bean crop:

The average numbers of mites associated was with an average of 33.7 mites/fortnight. The percentages of the three mite suborders were 73.0, 24.9 and 2.1 for Acaridida, Actinedida and Gamasida, respectively. The numbers of coleopteran was with an average of 12.8 individuals. The proportions of mites and insects were 72.5% and 27.5%, respectively.

b. Sweet pea crop:

The population of mites averaged of 19.7 mites. The percentages of the three mite suborders were 79.2, 20.3 and 0.5% for Acaridida, Actinedida and Gamasida, consecutively. The population of coleopteran averaged 1.8 individuals. The proportions of mites and insects were 91.6% and 8.4%, successively.

c. Cowpea crop:

The population was with an average of 24.7 mites. The percentages of the three mite suborders were 84.6, 13.8 and 1.6 for Acaridida, Actinedida and Gamasida, successively. The population density of coleopterous insects was with an average of 4.4 insects. The percent of mites and insects were 84.9 and 15.1%, respectively.

d. Kidney bean crop:

The number of mites was with an average of 38.5 mites. The percentages of the three mite suborders were 77.7, 20.0 and 2.3 for Acaridida, Actinedida and Gamasida, respectively. The average numbers was with an average of 29.8 individuals. The percent of mites and insects were 56.4 and43.6%.

e. Fenugreek crop:

The mites represented by Acaridida and Actinedida and averaged 8.2 mites, the percentages were 79.3 and 20.7%, successively. The population of coleopterous insects was with an average of 1.0 individual. The percent of mites and insects were 89.1% and 10.9%, respectively.

f. Lupine crop:

The population of mites was with an average of 13.9 mites. The percentages of the three mite suborders were 79.9, 19.4 and 0.7 for Acaridida, Actinedida and Gamasida, consecutively. The population of coleopterous was with an average of 0.4 individuals. The proportion of mites and insects were 97.2% and 2.8%, respectively.

g. Lentil crop:

The population of mites was with an average of 84.2 mites. The percentages of the three mite suborders were 85.0, 11.4 and 3.6 for

Acaridida, Actinedida and Gamasida, consecutively. The population density of coleopteran was with an average of 17.8 individuals. The percent of mites and insects were 82.5% and 17.5%, respectively.

h. Chickpea crop:

The population of mites was with an average of 37.7 mites. The percentages of the three mite suborders were 76.4, 21.5 and 2.1 for Acaridida, Actinedida and Gamasida, successively. The population density of coleopteran was with an average of 12.5 individuals. The percent of mites and insects were 75.1% and 24.9%.

i. Crushed broad bean (bi-product):

The population was with an average of 120.5 mites. The percentages of the three mite suborders were 91.0, 8.3 and 0.7 for Acaridida, Actinedida and Gamasida, respectively. The population of coleopterous insects was with an average of 7.6 individuals. The percent of mites and insects were 94.1% and 5.9%, successively.

J. Crushed soybean (bi-product):

The population was with an average of 47.3 mites. The percentages of the three mite suborders were 87.3, 11.2 and 1.5 for Acaridida, Actinedida and Gamasida, respectively. The population of coleopterous insects was with an average of 7.4 individuals. The percent of mites and insects were 86.5% and 13.5%, respectively.

The preliminary inspections confirmed that there were three criteria of association mites with the stored ten legume and bi-product crops, i.e. low, moderate and high. The following points had been established and clarified:

1. The occurrence of acaridid mites was found in high criterion, followed by coleopterous insects, actinedid and gamasid mites. It was ranked as the first one on the ten-stored legume crops.
2. The infestation by of acaridid mites is responsible for the high fluctuation of the total mites from a time to another.
3. The infestation by coleopterans took place as the second rank.
4. The occurrence of actinedid and gamasid mites almost was noticed in a few numbers during spring and summer seasons. They were ranked as the third and the fourth rank.
5. Regard to the association of the three mite suborders, results indicated that stored crushed broad bean as bi-product and lentil crop were with high criteria followed by bi-product of soybean, kidney bean, chickpea, broad bean and cowpea as moderate criteria.
6. According to the infestation by coleopterous insects, data confirmed that stored kidney bean crop was ranked the first one followed by lentil, broad bean, chickpea, crushed broad bean and crushed soybean.
7. The infestations of acaridid mites and coleopterous insects on storage room were higher in spring and summer seasons than autumn and winter seasons.
8. The three remained stored crops; e.g. sweet pea, lupine and fenugreek have the least numbers of occurrence of both arthropods collection.
9. Approximately the occurrence of gamasid mites was in very scarcely numbers in all stored crops under consideration.

1.1.2. The second season (July 2000 – June 2001):

Samples of four stored legumes (broad bean, kidney bean, cowpea and lentil) and two bi-product crops (crushed broad bean and crushed soybean) were collected from storage room and investigated. These stored six crops were chosen from the previous preliminary.

a. Broad bean crop:

The population densities of mites have three annual peaks of abundant. The first was the highest one in October 2000. The second and the third pecks were observed during April 2001 and June 2001, respectively. The coleopterous insects infested stored broad bean with two peaks during October 2000 and June 2001, successively. The proportions of mites and insects were 81.1% and 18.9%, respectively.

b. Kidney bean crop:

The total numbers of mites approximately equal the total numbers of coleopterous insects. The occurrence of the total mites was with three peaks. The first one was the highest in August. The second and third peaks were noticed in November 2000 and April 2001. The coleopterous insects occurred with four peaks. The first was the highest in July 2000. The second and the third peaks were in low numbers in September 2000 and January 2001, successively. The fourth one was also in a high number during June 2001. The percentages of mites and coleopterans occurrence were 49.9% and 50.1%, respectively.

c. Cowpea crop:

The total numbers of mites occurred with three peaks. The first one occurred in October 2000. The second peak was found in April 2001. The third peak the highest was observed in June 2001. The coleopterous insects infested stored cowpea with only one peak only in June 2001. The percentages of mites and insects were 84.3% and 15.7%, respectively.

d. Lentil crop:

The total numbers of mites occurred with high three peaks. The first one occurred in October 2000. The second peak was scored in April 2001. The third peak the highest was observed in June 2001. The coleopterous insects infested stored lentil crop with one peak only in July 2000. The proportions of mites and coleopterans occurrence were 81.5% and 18.5%, successively.

e. Crushed broad bean crop:

The occurrence of mites was with two peaks. The first one occurred in October 2000. The second peak was noticed in June 2001. The coleopterans infested stored crushed broad bean with three small peaks in November 2000, March and June 2001. The proportions of mites and coleopterans occurrence were 86.7% and 13.3%, respectively.

f. Crushed soybean crop:

The occurrence of mites was with two peaks. The first one occurred in October 2000. The second peak was noticed in June 2001. The coleopterous insects infested stored crushed soybean with two small peaks in October 2000 and June 2001. The proportions of mites and coleopterans occurrence were 91.2% and 8.8%, respectively.

The susceptibilities of six-stored legume crops to association and/or infestation by mites and coleopterous insects were arranged in descending order. There were two criteria i.e., moderate and high. Results clearly indicated that the susceptibility of six-stored legume crops for associations of mites in this descending order as the following ranks. Lentil took place as the 1st rank followed by crushed broad bean as the 2nd rank, broad bean as the 3rd rank and then kidney bean as the 4th rank. While the infestations with coleopterans were ranked as the following ranks: kidney bean took place the 1st rank followed by lentil as the 2nd rank, broad bean as the 3rd rank and crushed broad bean as the 4th rank. Cowpea and crushed soybean were ranked as the 5th and the 6th ranks.

Our results indicated that most of mites and coleopterous insects increased by increasing in temperature degrees, while relative humidity has a little effect on the populations of these pests in storage.

1.1.3. Statistical analyses:

There were highly significant differences among the population densities of the mites and the coleopterous insects associated with the six-stored legume crops during monthly observations and among their susceptibilities. In addition, the interaction effects of months and six crop kinds have highly significant differences.

a. <u>Effect of monthly inspections on the population densities</u>:

There were significant differences among the effect of monthly inspections on the population densities for each of the three mite suborders and coleopterans associated with the six-stored legume crops. The following data explain the differences and ranks in the populations.

1. **Acaridid mites:** High significantly differences were found among the mean number of these mites in June 2001 and the mean numbers of the remaining eleven monthly inspections and ranking the 1st. While, the mean numbers in July, August and September had no significant differences, they were ranked the 9th, 8th and 10th, respectively.
2. **Actinedid mites:** Significantly difference was noticed between the population density in June 2001 and the population densities of the resting eleven months and ranking the 1st. While no significant differences among the population densities in July (the 8th rank), September 2000 (the 6th rank) and March 2001 (the 7th rank) or between the population density in April (the 3rd rank) and May 2001 (the 2nd rank) were observed.
3. **Gamasid mites:** The mean number of these mites in April 2001 had significant difference with the means of resting eleven months and

ranking the 1st. While the mean numbers in July, August, November 2000, February and May 2001 had no significant differences. They were ranked the 5th, 8th, 6th, 9th and 7th, successively.

4. **Coleopterous insects:** There was significantly difference either between the population density in July 2000 (the 1st rank) and the population in June (the 2nd rank) or the population in May 2001 (the 3rd rank). All the three categories were significantly different with the population densities of the resting nine months.

b. Comparison among the susceptibility of the six stored legumes to infestation or association with mites and coleopterans:

There were significant differences among the susceptibility of the six-stored legume crops to infestation or association with mites and insects. The following points had been established and clarified:

1. **Acaridid mites:** High significantly differences were found among the infestation susceptibility of stored lentil crop by acaridid mites and the susceptibilities of the remaining five stored legumes crops and ranking the 1st. While, the susceptibilities of stored broad bean, Kidney bean and crushed broad bean had no significant differences, they were ranked the 4th, 3rd and 2nd, successively. In the same time they had significant differences between their susceptibilities and the susceptibility either of stored cowpea (the 5th rank) or crushed soybean (the 6th rank).

2. **Actinedid mites:** No significantly difference was found between the infestation or association susceptibility of stored lentil and crushed broad bean with these mites, they were ranked the 1st and 2nd, while there were significantly differences between them and the susceptibilities of the resting four stored crops. In addition, there was no significantly difference either between the susceptibility of stored broad bean (the 3rd rank) and stored kidney bean (the 4th rank) or

between the susceptibility of stored cowpea (the 5th rank) and crushed soybean (the 6th rank).

3. **Gamasid mites:** There was significantly difference between the association susceptibility with stored lentil (the 1st rank) and the association susceptibilities of five remaining stored crops. The susceptibilities with stored broad bean, kidney bean, crushed broad bean and crushed soybean had no significant differences. They were ranked the 6th, 4th, 3rd and 5th, consecutively.
4. **Coleopterous insects:** There was significantly difference between the infestation susceptibility of stored kidney bean (the 1st rank) and the infestation susceptibilities of the five resting stored legumes by these insects. Whilst, no significant difference was noticed either between the infestation susceptibility of stored broad bean (the 3rd rank) and stored lentil (the 2nd rank) or between stored cowpea (the 5th rank) and stored crushed broad bean (the 4th rank) or stored crushed soybean (the 6th rank). Also, significant difference was found between stored crushed broad bean and crushed soybean.

c. <u>Correlation of mites and coleopterans with climatic factors:</u>

1. The population density of actinedid mites showed a positive and strongly significant correlated with acaridid mites and air temperature, while had a negative and insignificant correlation with R.H% and positive insignificant correlation with the population densities of gamasid mites and coleopterous insects.
2. The population density of gamasid mites showed positive significant with the population of acaridid mites and insignificant correlation with the population density of coleopterans and air temperature, while a negative and insignificant correlation was noticed with R.H.%.

3. The population of coleopterous insects showed a positive and slightly significant correlation with air temperature, while had no significant correlation with the population of acaridid mites and R.H.%.
4. There was positive or negative and insignificant correlation between air temperature and the population of acaridid mites or R.H.%.
5. Therefore, from the above-mentioned data, it could be observed that air temperature has an important role in the distribution of actinedid mites, coleopterans and slight effect on acaridid and gamasid mites.
6. In contrary, R.H.% has a low effect on the populations.

1.1.4. Comparison between the population densities of the mites and coleopterans associated with six stored legumes in both seasons:

The population densities of acaridid mites infesting six stored legumes were higher in the second season than that of the first season, except for both bi-products the opposite was true.

The population densities of actinedid mites associated with the six stored legumes were higher in the first season than that the second season, except for cowpea and lentil the opposite was true.

The population densities of gamasid mites associated the six stored legumes were higher in the second season than in the first season.

The population densities of the total mites associated with the six stored legumes were similar to those of acaridid mites. Because of, as aforementioned results the high population densities of acaridid mites affected the population fluctuation of the total mites.

The population densities of coleopterous insects infesting six stored legumes were higher in the second season than that of the first season, except for crushed broad bean the inverse trend was noticed.

1.2. <u>Species composition</u>:

A total of thirty-six mite species belonging to twenty-six genera following seventeen families of the three mite suborders were collected and identified. However, Acaridida represented by sixteen spices belonging to thirteen genera following six families. Actinedida represented by twelve spices belonging to eight genera following seven families. Gamasida represented by eight spices belonging to five genera following four families.

It could be elucidated that the most common mite species infesting the six stored legume crops as pests were ***T. putrescentiae***, ***B. freemani***, ***L. destructor*** and ***G. domesticus***. Relatively the most abundant species of predacious mites were ***C. malaccensis*** and ***B. mali***.

A total of seven insect species belonging to five genera following three families of order Coleoptera were collected and recovered from the six legume crops. However, it could be noticed that the most abundant coleopterous species infesting the six-stored legume crops as pests were ***C. maculatus***, ***Tribolium castaneum*** and ***Sitophilus oryzae***. However, ***C. chinensis*** infested stored cowpea only, ***B. rufimanus*** infested broad bean only and ***T. confusum*** highly infested lentil only, while ***B. incarnatus*** infested stored broad bean, lentil and crushed broad bean crops.

a. **Broad bean:** A total of twenty-three mite species following sixteen genera belonging to eleven families and five coleopteran species following five genera belonging to three families.

b. **Kidney bean:** A total of fifteen mite species following thirteen genera belonging to nine families and three coleopteran species following three genera belonging to three families.

c. **Cowpea:** A total of eighteen mite species following fourteen genera belonging to nine families and four coleopteran species following three genera belonging to three families.

d. **Lentil:** A total of twenty-six mite species following twenty genera belonging to fourteen families and five coleopteran species following four genera belonging to three families.

e. **Crashed broad bean:** A total of fifteen mite species following eleven genera belonging to eight families and four coleopteran species following three genera belonging to three families.

f. **Crushed soybean:** A total of fifteen mite species following eleven genera belonging to eight families and two coleopteran species following two genera belonging to two families.

1.3. Some ecological aspects between mites and coleopterans:

There are two types of relationships between acaridid mites and coleopterous insects under storage conditions. Firstly, is the competition and secondly is the predation. The competitions among three mite species (***T. putrescentiae, L. destructor*** and ***G. domesticus***) and two coleopterous species (***C. maculatus*** and ***T. castaneum***) were studied.

2. Biological Studies:

The biology ***C. malaccensis*** and ***A. sollers*** on eggs of the two coleopterous beetle species were evaluated during the period from January to June 2003.

2.1. Biology of bruchid beetles:

2.1 1. *Biology of Callosobruchus maculatus*:

2.1.1.1. Developmental stages and life span:

a. Egg stage: The incubation period of eggs averaged 9.0 days.

b. Larval stage: It averaged 23.0 days.

c. Pupal stage: It averaged 7.0 days to moult and reach the adult stage.

d. Adult stage: The adult longevity averaged 27.4 days and involves the following three periods:

- ***Pre-oviposition period:*** After the last moulting of the pupal stage, the adults emerge to go across the holes in cowpea seeds. Mating between a male and a female lasted 1 – 9 min. however; all crossing took place for about 20 to 25 min. during this period. The adult female beetle stays a short time (one day only) to lay its first egg on cowpea seed.
- ***Oviposition period:*** It averaged 16.8 days.
- ***Post-oviposition period:*** It averaged 9.6 days.

e. Life cycle: The life cycle averaged 39.0 days.

f. The pre-reproductive period: It includes incubation period, larval, pupal developmental periods and the pre-oviposition period of an adult female. However, It is nearly equal to the life cycle plus the pre-oviposition period.

g. The reproductive period: It was counted as the number of days for which a given female continued to reproduce. However, here it could be considered the oviposition period.

h. The post-reproductive period: It was estimated as the time elapsed between the date of laying the last egg and the date of death of the mother. Here it could be considered the post-oviposition period.

i. The life span: The life span was calculated by summing up the above mentioned three periods. It averaged 66.4 days.

2.1.1.2. Fecundity and efficacy of male mating of C. maculatus:

a. Fecundity: At mating 5 males x 5 females, the average number of eggs was 60.3 eggs/female, while, the averages were 40.3, 38.2 and 51.0 eggs/female for mating between one male and 1, 2 and 3 females, respectively.

b. Egg hatchability percentages: The averages of hatching eggs were higher in cross of 5 males x 5 females than those of male x 2 females followed by male x female and the lowest one was male x 3 females. Where the averages were 46.9, 28.8, 22.3 and 20.0 eggs/female, successively. Therefore, similar trend was noticed for the hatchability percentages to those of the averages.

c. Mortality percentages: The averages of unhatching eggs were lower in cross of male x 2 females than those of 5 males x 5 females followed by male x female and the highest numbers was for cross male x 3 females. However, the mortality percentages of eggs were found in contrary to those of the hatchability percentages.

2.1.2. Biology of Callosobruchus chinensis:

2.1.2.1. Developmental stages and life span:

a. Egg stage: The incubation period of eggs averaged 6.2 days.

b. Larval stage: It averaged 30.6 days.

c. Pupal stage: It averaged 6.6 days.

d. Adult stage: It was divided into:

- *Pre-oviposition period:* The adults emerge to go across the holes in cowpea seeds. Mating between a male and a female lasted 1 – 7 min. however; all crossing took place for about 30 to 35 min. during this period. The adult female beetle stays a short time 1 – 2 days to lay its first egg on the cowpea seed.
- *Oviposition period:* It averaged 12.2 days.
- *Post-oviposition period:* It averaged 10.8 days.
- *Adult longevity:* It averaged 24.2 days.

e. Life cycle: The life cycle averaged 43.4 days.

f. The life span: It averaged 67.6 days during.

2.1.2.2. Fecundity and efficacy of male mating C. chinensis:

a. Fecundity: In mating 5 males x 5 females, the average number of eggs was 26.1 eggs/female, while the averages were 37.3, 24.8 and 29.4 eggs/female for mating between one male and 1, 2 and 3 females, consecutively.

b. Egg hatchability percentages: The averages of hatching eggs were higher in cross of 5 males x 5 females than those of male x female followed by male x 3 female and the lowest one was male x 2 females. Where the averages were 20.3, 20.0, 14.3 and 13.2 eggs/female, successively. However, the hatchability percentages were differed between the crosses, where these proportions were 77.6% for 5 males x 5 females, 54.6% for male x male, 53.0% for male x 2 females and the least percent was 48.7% for male x 3 females.

c. Mortality percentages: The averages of unhatching eggs were lower in cross of male x 2 females than those of 5 males x 5 females followed by male x female and the highest numbers was for cross male x 3 females.

2.1.3. Comparison between reproductive potentiality of both beetles:

The reproductive potentiality of adult females for laying eggs was decreased when beetle males were crossed with increasing of female numbers or the sex ratio between male to female increased from 1: 1 reaching 1: 2 or 1: 3 male to females, respectively. However, the cross 5 males x 5 females (sex ratio was 1: 1) showed the highest numbers of deposited eggs and hatchability.

However, the high differentiation of hatching percentages in crosses five males x five females for both bruchid beetles may be due to the following suggestions:

. Group of males and females enhanced the fertilization process.

2. Any male can be mated more than one female.
3. There is a great chance for mating of any female by more one male.
4. The sex ratio was as the theoretical ratio (1: 1), when sex ratio differed than the theoretical ratio increasing or decreasing on numbers of offspring could be attributed to efficacy of male mating. Taken in our consideration those females are responsible for reproduction of the offspring.

2.2. Biology of cheyletid mites:

Two reasons for which the predacious mites ***C. malaccensis*** and ***A. sollers*** were reared i.e., to study the life span and the efficiency on preying eggs of both bruchid beetle species.

2.2.1. *Biology of the predatory mite Cheyletus malaccensis*:

The duration in days of females and males of the predatory mite ***C. malaccensis*** reared on eggs of ***C. maculatus*** and ***C. chinensis*** was given.

2.2.1.1. Developmental stages and life span on eggs of C. maculatus:

1. ***Egg stage:*** The incubation period averaged 6.3 days for females, while for males averaged 6.7 days.
2. ***Larval stage:*** The developmental period of larvae averaged 13.0 days for females. For males averaged 10.0 days.
3. ***Nymphal stage:*** It averaged 27.7 days to reach the adult female. In fact, there are two nymphal stages for female only i.e., the protonymphal stage duration averaged 10.3 days. The deutonymphal stage averaged 17.3 days. Duration of nymphal stage for adult male has one stage only. It averaged 13.7 days.
4. ***Adult stage:*** The longevity of adult male is shorter than that of the adult female. It averaged 6.3 days. The female longevity averaged 20.3 days. The adult female longevity involves three periods:

- ***Pre-oviposition period:*** It averaged 7.3 days.
- ***Oviposition period and fecundity:*** The oviposition period averaged 6.7 days. The number of eggs produced per one female averaged 6.9 eggs/female.
- ***Post-oviposition period:*** It averaged 6.3 days.

5. ***Life cycle:*** For female averaged 47.0 days. For male averaged 30.3 days.
6. ***Life span:*** For female averaged 67.3 days. For male averaged 36.7 days.

2.2.1.2. Developmental stages and life span on eggs of C. chinensis:

1. ***Egg stage:*** The incubation period averaged 7.0 days for female, while for male averaged 5.3 days.
2. ***Larval stage:*** The developmental period of larvae averaged 10.3 days for females. For males averaged 10.3 days.
3. ***Nymphal stage:*** It averaged 26.7. The duration of protonymphal stage averaged 10.0 days. The duration of deutonymphal stage averaged 16.7 days. The duration of nymphal stage of adult male averaged 10.7 days.
4. ***Adult stage:*** The longevity of adult male averaged 6.0 days. For female averaged 20.0 days.

- ***Pre-oviposition period:*** It averaged 6.3 days.
- ***Oviposition period and fecundity:*** The oviposition period averaged 6.0 days. The number of eggs produced per one female averaged 7.9 eggs/female.
- ***Post-oviposition period:*** It was with an average of 7.7 days.

5. ***Life cycle:*** For female averaged 44.0 and for male averaged 26.3 days.
6. ***Life span:*** For female averaged 64.3 and for male averaged 32.3 days.

2.2.2. *Biology of the predatory mite Acaropsis sollers*:

2.2.2.1. Developmental stages and life span on eggs of C. maculatus:

1. Egg stage: The incubation period averaged 5.7 days for females, while for males averaged 5.7 days. The hatching larvae did not feed and remain near the eggshells.

2. Nymphal stage: It averaged 9.3 days to reach the adult female. The duration of nymphal stage of male averaged 9.0 days. In fact, there is one nymphal form only for female and male.

3. Adult stage: The male longevity averaged 6.3 days. The female longevity averaged 15.3 days.

- ***Pre-oviposition period:*** It averaged 4.7 days.
- ***Oviposition period and fecundity:*** The oviposition period averaged 5.0 days. The average number of eggs produced per one female averaged 11.3 eggs/female.
- ***Post-oviposition period:*** It averaged 5.7 days.

4. Life cycle: For female averaged 15.0 and for male averaged 6.3 days.

5. Life span: For female averaged 30.3 and for male averaged 18.7 days.

2.2.2.2. Developmental stages and life span on eggs of C. chinensis:

1. Egg stage: The incubation period averaged 4.7 days for females, while for males averaged 4.0 days.

2. Nymphal stage: It averaged 9.0 days to reach the adult female. For adult male averaged 6.3 days.

3. Adult stage: The male longevity averaged 6.0 days. For female longevity averaged 14.3 days. The adult female longevity involves three periods:

- ***Pre oviposition period:*** It averaged 4.3 days.

- ***Oviposition period and fecundity:*** The oviposition period was with an average of 4.3 days. The number of eggs produced per one female was with an average of 8.9 eggs/female.
- ***Post-oviposition period:*** It averaged 5.7 days.

4. ***Life cycle:*** For female averaged 13.7 and for male averaged 11.0 days.
5. ***Life span:*** For female averaged 28.0 and for male averaged 17.0 days.

2.2.3. Comparison between bionomics of C. malaccensis and A. sollers:

The life cycle and fecundity were differed between the two predacious mite species and between the same mite species during their rearing on eggs of the two-bruchid beetle species.

The average duration periods of females and males of the predacious mite ***C. malaccensis*** was longer than the average duration periods of females and males of the predacious mite ***A. sollers*** when they were reared on eggs of ***C. maculatus*** and ***C. chinensis***. Whatever, the life span of male for either ***C. malaccensis*** or ***A. sollers*** was shorter than the span of the female.

The fecundity of ***C. malaccensis*** was lower than the fecundity of ***A. sollers*** when they were reared on eggs of the both bruchid beetle species. In the same time, the average number of eggs laying by ***A. sollers*** was higher for females reared on eggs of ***C. maculatus*** than that on eggs of ***C. chinensis***. The opposite trend was noticed for ***C. malaccensis***.

As results of observations on the bionomics of both predacious mite species, it could be concluded and clarified the following points:

1. The female life cycle of the predatory mite ***C. malaccensis*** has four developmental immature stages i.e., egg, larva, protonymph and deutonymph. While, the male life cycle has three developmental immature stages only viz., egg, larva and nymph.

2. The female and male life cycles of the predatory mite ***A. sollers*** have three developmental stages i.e., egg, larval and nymphal stages. In addition, larvae survived very few hours and did not feed.
3. The bionomics of ***A. sollers*** female and male was carried out for the first time at least in Egypt.
4. Cannibalism was abundance in the adult stages of both mite spices especially at the time that the preys (eggs of insects, immature and adult stages of other mite species) were absent or in scarce numbers.

3. Biological Control:

The predation capacities were determined every 24 or 48 hrs by counting the number of punctured and non-punctured intact egg chorines per Petri dish. The daily consumption rates and predation percentages on egg stage of both bruchid beetle species were estimated.

3.1. Efficiency of *Cheyletus malaccensis* as a biological control agent:

3.1.1. Predation capacity of C. malaccensis on C. maculatus eggs:

1. **Larval stage:** Female larva of this mite species consumed eggs with an average of 16.9 eggs. While male larva preyed upon the beetle eggs with an average of 13.2 eggs.
2. **Nymphal stage:** The feeding capacity of female nymph averaged 55.3 eggs. The average numbers of consumption eggs by protonymph and deutonymph were 17.8 and 37.5 eggs, respectively. The feeding capacities of male nymph on prey eggs averaged 23.7 eggs.
3. **Life cycle:** The mite females during their life cycles preyed upon ***C. maculatus*** eggs with an average of 72.3 eggs. The mite males during their life cycles fed on eggs with an average of 36.8 eggs.
4. **Adult longevity:** The predation capacity during longevity of adult female averaged 39.9 eggs/female. The predation capacity during

longevity of adult male averaged 12.2 eggs/male. In the pre-oviposition period the attacking prey eggs averaged 17.8 eggs, during the oviposition period the adult female consumed eggs with an average of 14.9 eggs and in post-oviposition period the adult female fed on prey eggs with an average of 7.2 eggs.

5. **Life span:** The mite female during the whole duration periods preyed upon the eggs with an average of 112.1 eggs/female. The mite male attacked prey eggs with an average of 49.0 eggs/male.

3.1.2. Predation capacity of C. malaccensis on C. chinensis eggs:

1. **Larval stage:** Female larva fed on prey eggs with an average of 13.2 eggs, while male larva fed on prey eggs with an average of 13.7 eggs.
2. **Nymphal stage:** The feeding capacity of this mite species female nymph during averaged 55.7 eggs. The average numbers of consumption eggs by protonymph and deutonymph were 18.0 eggs and 37.7 eggs, successively. The feeding capacity of male nymph during its duration on prey eggs was with an average of 18.7 eggs.
3. **Life cycle:** The mite female during its life cycle preyed upon *C. chinensis* eggs with an average of 68.9 eggs. The mite male during its life cycle fed on prey eggs with an average of 32.3 eggs.
4. **Adult longevity:** The predation capacity during longevity of adult female averaged 37.7 eggs/female. The predation capacity during longevity of adult male averaged 9.2 eggs/male. In the pre-oviposition period the attacking prey eggs by female averaged 14.7 eggs, during the oviposition period the adult female consumed eggs with an average of 17.5 eggs and in post-oviposition period the adult female fed on eggs with an average of 5.5 eggs.

5. **Life span:** The mite female during whole duration periods preyed upon prey eggs with an average of 106.5 eggs/female. The mite male attacked prey eggs with an average of 41.5 eggs/male.

3.2. Efficiency of *Acaropsis sollers* as a biological control agent:

3.2.1. Predation capacity of A. sollers on C. maculatus eggs:

1. **Nymphal stage:** The feeding capacities of this mite species female nymph during its duration beetle eggs averaged 24.9 eggs. The feeding capacities of male nymph on prey eggs averaged 15.0 eggs.
2. **Life cycle:** The mite females during their life cycles preyed upon beetle eggs with an average of 24.9 eggs. The mite males during their life cycles fed on eggs with an average of 15.0 eggs.
3. **Adult longevity:** The predation capacity during longevity of adult female on *C. maculatus* eggs averaged 64.0 eggs/female. The predation capacity on prey eggs during longevity of adult male averaged 17.8 eggs/male. However in the pre-oviposition period the attacking prey eggs by female averaged 21.7 eggs, during the oviposition period the adult female consumed prey eggs with an average of 23.9 eggs and in post-oviposition period the adult female fed on prey eggs with an average of 19.7 eggs.
4. **Life span:** The mite female during the whole duration periods preyed upon the eggs of *C. maculatus* with an average of 88.9 eggs/female. The mite male attacked prey eggs with an average of 32.8 eggs/male.

3.2.2. Predation capacity of A. sollers on C. chinensis eggs:

1. **Nymphal stage:** The feeding capacity of this mite species female nymph during its duration on the pulse cowpea beetles eggs averaged 21.2 eggs. The feeding capacities of male nymph on prey eggs averaged 17.7 eggs.

2. **Life cycle**: The mite female during its life cycle preyed upon *C. chinensis* eggs with an average of 21.2 eggs. The mite male during its life cycle fed on prey eggs with an average of 17.7 eggs.

3. **Adult longevity**: The predation capacity during longevity of adult female averaged 56.0 eggs/female. The predation capacity during longevity of adult male averaged 9.2 eggs/male. In the pre-oviposition period the attacking prey eggs by female averaged 17.5 eggs, during the oviposition period the adult female consumed eggs with an average of 19.9 eggs and in post-oviposition period the adult female fed on 18.6 eggs.

4. **Life span**: The mite female during the whole duration periods preyed upon the pulse cowpea beetle eggs with an average of 77.2 eggs/female. The mite male attacked prey eggs with an average of 33.5 eggs/male.

3.3. Comparison between the efficiency of the two predacious mites:

3.3.1. Comparison among the predation capacities of stages of the two predacious mite species:

The comparison among the predation capacities of any stage i.e., larvae, nymphs and adults of *C. malaccensis* and *A. sollers* on eggs of the two bruchid beetle species were carried out.

1. ***Larval stage:*** The predation capacities of *C. malaccensis* female larvae on eggs of *C. maculatus* were higher than that of male larvae, while it was equal on eggs of *C. chinensis*.

2. ***Nymphal stage:*** The feeding capacities of *C. malaccensis* female and male nymphs were higher on eggs of *C. maculatus* and *C. chinensis* than those of *A. sollers*. The feeding capacities of female nymphs were arranged in this descending order *C. malaccensis* females on eggs of *C. chinensis*, *C. maculatus* followed by females *A. sollers* on

eggs of *C. maculatus* and *C. chinensis*. The feeding capacities of male nymphs were arranged in this descending order *A. sollers* on eggs of *C. chinensis*, *C. maculatus* followed by *C. malaccensis* on eggs of *C. chinensis* and *C. maculatus*.

3. ***Life cycle:*** Females and males of *C. malaccensis* consumed eggs of *C. maculatus* and *C. chinensis* more than females and males of *A. sollers* during their life cycles. The predation capacities during females' life cycle were arranged in this descending order *C. malaccensis* on eggs of *C. maculatus*, *C. chinensis* followed by *A. sollers* on eggs of *C. maculatus* and *C. chinensis*, respectively. The predation capacities during males' life cycle were arranged in this descending order *C. malaccensis* on eggs of *C. maculatus*, *C. chinensis* followed by *A. sollers* on eggs of *C. chinensis* and *C. maculatus*, successively.

4. ***Adult stage:*** The predation capacities during the adult longevity were higher in *A. sollers* females and males than those of *C. malaccensis*. The predation capacities during females' longevity were arranged in this descending order *A. sollers* on eggs of *C. maculatus*, *C. chinensis* followed by *C. malaccensis* on eggs of *C. maculatus* and *C. chinensis*, respectively. The predation capacities during males' longevity were arranged in the same trend of female's longevity.

5. ***Life span:*** The predation capacities during the life span of females and males of *C. malaccensis* were higher than of those of *A. sollers*. The predation capacities during females' life span were in this descending order *C. malaccensis* on eggs of *C. maculatus*, *C. chinensis* followed by *A. sollers* on eggs of *C. maculatus* and *C. chinensis*, respectively. The predation capacities during males' life span were in this descending order *C. malaccensis* on eggs of *C.*

maculatus*, *C. chinensis followed by ***A. sollers*** on eggs of ***C. chinensis*** and ***C. maculatus***, successively.

It is noteworthy to mention that, ***C. malaccensis*** females during their duration consumed eggs of ***C. maculatus*** and ***C. chinensis*** more than that of ***A. sollers*** females and males. This could be ascribed to the long life cycles of ***C. malaccensis*** females that have larval, protonymphal and deutonymphal stages feed on eggs of the preys. While, the short life cycle of ***A. sollers*** females could be attributed to that females have non-feeding larvae and one nymphal stage only. Data indicated that although ***C. malaccensis*** female consumed prey eggs more than ***A. sollers*** female during their life span, ***A. sollers*** female and male consumed eggs of both beetle species more than those of ***C. malaccensis*** during their adult longevities. This due to that adult of ***A. sollers*** was the most voracious predatory mite than ***C. malaccensis***. Therefore, this phenomena took our attention to compare the daily rate of consumption per each stage and the efficiency percentages of both predacious mite species.

The daily consumption rate and consumption percentage were calculated as the following two equations:

$$\textbf{Daily consumption rate} = \frac{\text{Average no. of consumed eggs by any stage}}{\text{Average no. of survival days of the same stage}}$$

$$\textbf{\% of consumption} = \frac{\text{Average no. of consumed eggs by any stage}}{\text{Total average no. of consumed eggs during life span}} \times 100$$

3.3.2. Comparison the daily consumption rates of the two predacious mite species:

1. <u>Larval stage:</u> The daily consumption rates of ***C. malaccensis*** female and male larvae on eggs of ***C. maculatus*** were 1.3 eggs/larva/day and equal on eggs of ***C. chinensis***.

2. ***Nymphal stage:*** The daily consumption rates of ***C. malaccensis*** female and male nymphs were lower on eggs of ***C. maculatus*** and ***C. chinensis*** than those of ***A. sollers***. The daily consumption rates of female nymphs were higher than of those of male nymphs. Except, in the consumption rate of male nymphs of ***A. sollers*** on eggs of ***C. chinensis*** it was higher than female nymphs, where the rates were 2.8 and 2.4 eggs/nymph/day for male and female nymphs, respectively.

3. ***Life cycle:*** The daily consumption rate of ***C. malaccensis*** female was lower than that of ***A. sollers*** female on eggs of ***C. maculatus***, while for males the daily consumption rates were equal (1.2 eggs/male/day). The daily consumption rate of ***C. malaccensis*** female was higher than that of ***A. sollers*** female on eggs of ***C. chinensis***, while for males the daily consumption rates were differed and in ***A. sollers*** male was higher than in female.

4. ***Adult stage:*** The daily consumption rates during the adult longevity were higher in ***A. sollers*** females and males than those of ***C. malaccensis***. Also, the daily consumption rates of females in both predacious mites were higher than that of males in all treatments.

5. ***Life span:*** The daily consumption rates during the life span of females and males of ***C. malaccensis*** were lower than of those of ***A. sollers***.

3.3.3. Comparison the consumption percentages of the two predacious mite species:

1. ***Larval stage:*** The consumption percentages of ***C. malaccensis*** male larvae on eggs of ***C. chinensis*** (33.0%) and ***C. maculatus*** (26.9%) were higher than that of female larvae on eggs of ***C. chinensis*** (12.4%) and ***C. maculatus*** (15.1%). In addition, the consumption percentages of ***C. malaccensis*** female larvae on eggs of ***C. maculatus*** were lower than that on eggs of ***C. chinensis***.

2. __*Nymphal stage:*__ The consumption percentage of ***C. malaccensis*** female nymphs was lower on eggs of ***C. maculatus*** (49.3%) than that of ***C. chinensis*** (52.3%). The consumption percentage of ***C. malaccensis*** male nymphs was higher on eggs of ***C. maculatus*** (48.1%) than that of ***C. chinensis*** (45.1%). The consumption percentage of ***A. sollers*** female nymphs was little higher on eggs of ***C. maculatus*** (28.0%) than that of ***C. chinensis*** (27.5%). The consumption percentage of ***A. sollers*** male nymphs was lower on eggs of ***C. maculatus*** (45.7%) than that of ***C. chinensis*** (52.8%).

3. __*Life cycle:*__ The consumption percentages during females' life cycle were lower than that of males on eggs of both bruchid beetle species. The consumption percentage of ***C. malaccensis*** female during its life cycle was equal (64.5% and 64.7%) on eggs of ***C. maculatus*** and ***C. chinensis***, respectively. Also, the consumption percentage of ***A. sollers*** female during its life cycle was little higher on eggs of ***C. maculatus*** (28.0%) than that on eggs of ***C. chinensis*** (27.5%).

4. __*Adult stage:*__ The consumption percentages of adult longevities were higher in ***A. sollers*** females and males (72.0, 72.5 and 54.3, 47.2%) than those of ***C. malaccensis*** (35.6, 35.4 and 24.9, 22.2%) on eggs of ***C. maculatus*** and ***C. chinensis***, successively. Also, the consumption percentages of females in both predacious mites were higher than that of males.

The predation efficiency of mites is depended on the period of each stage, number and abundance of the preys and the activity of the predacious mites themselves. Furthermore, the climatic conditions such as storage temperature, interaction between temperature and relative humidity, moisture of crops and type of the crops as well as the behaviour of stored product pests and predacious mites are limitation factors for increasing or decreasing the efficiency.

As a final conclusion, the efficiency of the two predatory mite species as biological control agents against the bruchid beetles eggs, it could be concluded and clarified the following points:

1. Highly differences were detected between the average numbers of prey eggs, which were consumed by the two mite species.
2. From the theoretical point, the cheyletid predatory mite ***C. malaccensis*** consumed number of prey eggs more than that the predatory mite ***A. sollers*** during its life history, that due to the length of life span of the first mite species.
3. From the practical point, the cheyletid predatory mite ***A. sollers*** was the most voracious predator preyed upon the bruchid beetle eggs than that of ***C. malaccensis*** that ascribed to the short time of life span. This due to the highly rate and the percentage of consumption.
4. The adult females of cheyletid mite species prey upon prey eggs more than the adult males under the laboratory conditions. This is due to the length of adult females' duration.
5. It could be suggested that the predatory mite species play an essential role in the process of mass rearing and have influence on quality indices of bruchid beetle cultures. And it must be considered in planning of biological control programs in stores. That needs more inspections and research work to select and identify the suitable methods to controlling such these insect pests in storage.